Evaluation of Habitat Suitability Index Models for Assessing Biotic Resources

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Abstract.—Existing habitat suitability index (HSI) models are evaluated for assessing the biotic resources on Champion International Corporation (CIC) lands with data from a standard and an expanded timber inventory. Forty HSI models for 34 species that occur in the Southern Appalachians have been identified from the literature. All of the variables for 14 models are provided (collected or calculated) from the standard or enhanced inventory and from other sources. Based on these results, we recommend using a land- and habitat-based approach such as landscape ecosystem classification to assess biotic resources because it will more efficiently accommodate all resources.

BACKGROUND

Maintaining biological diversity will be one of the most important environmental challenges of the 21st century. The single-species paradigm for endangered species conservation, largely a byproduct of the 1973 Federal Endangered Species Act, has been, at best, inequitable and, at worst, ineffective. Almost half of endangered species funding is directed toward 10 high-profile species, leaving only half allocated for the remaining 467 species (LaRoe 1993). Funding levels for the 10 high-profile species probably are not inappropriate; nevertheless, many little-known species are being overlooked.

Blunting the increasing loss of biological diversity will require an approach that is linked more clearly with ecological systems (Fiedler *et al.* 1993, LaRoe 1993). One approach to this problem is ecosystem management, a concept that has been conceptualized for decades (Leopold 1966). Such an approach to endangered species management is essential for several reasons. First, resource management problems are more complex than they were even a decade ago. Global issues such as increasing ultraviolet radiation and climate change were hardly considered in the 1970's and 1980's. Also, the legal climate has become more convoluted and confrontational. Second, because issues concerning biological diversity usually transcend jurisdictional lines, a landscape approach to conservation is warranted. However, to be effective, this will have to involve the voluntary cooperation of government (federal, state, and local) and private landowners. Finally, a landscape approach is more cost efficient than the single-species approach. We will never be able to address the inequities inherent in the single-species approach unless we can redirect our focus to the ecosystems that contain them.

It is important to recognize the increasing demands that our growing human population has for natural resources. At the same time, we must recognize that it is more efficient to conserve a species while it is still abundant than when it becomes imperiled. The concept of ecosystem management offers a framework for *a priori* endangered species management, while providing for the production of goods and services upon which humans depend.

This paper presents the results of a study conducted under a contract among Champion International Corporation (CIC), the National Fish and Wildlife Foundation, the National Council of the Paper Industry for Air and Stream Improvement, Inc., the National Biological Service, and the University of Tennessee. The purpose of the research was to evaluate ways of inventorying and monitoring a wide array of biotic resources on private lands in a cost-efficient manner. Specifically, the use of the standard CIC timber inventory with a few additional variables and habitat suitability index (HSI) models was considered.

HABITAT SUITABILITY INDEX MODELS

Habitat suitability index models quantify habitat suitability for species based on environmental variables thought to most affect species presence, distribution, or abundance. HSI models describe habitat suitability for a particular species, not population sizes or trends (Morrison *et al.* 1992). Their output ranges from 0 (totally unsuitable) to 1 (totally suitable) (U.S. Fish and Wildlife Service 1981). HSI models generally are developed species by species, and often are based on both research results and the experience of experts and managers.

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STUDY AREA

The Gulf Tract was chosen as the field site to test the procedures developed as part of this study. It is a 6,700-acre tract owned by CIC in east Tennessee adjacent to the North Carolina border. The terrain is mountainous as is typical of most of the extreme eastern part of Tennessee. The vegetation is predominately mature hardwoods.

FIELD METHODS FOR ENHANCED INVENTORY

An inventory of the Gulf Tract was conducted in July and August 1995. Data were collected on 579 systematically located plots using an enhanced version of the CIC standard timber inventory procedures. Standard timber measurements included tree species, diameter at breast height (dbh), total height, merchantable height for up to three products, age of one tree per plot for site index, and seedling and sapling counts by pine and hardwood. Data collected beyond the standard timber measurements included height to the base of the live crown on merchantable trees; dbh and total height on standing dead trees; percent cover of mid-level vegetation (3 to 15 feet in height); percent ground cover (less than 3 feet in height) from woody vegetation, grass, vines, and other vegetation; length and large-end diameter of down woody material; number of stumps larger than 12 inches in diameter and 12 inches high; and species and dbh for trees with dbh less than 5.0 inches. Merchantable and standing dead trees were tallied on a variable-radius plot. All other data were collected on a 1/50-acre plot.

METHODS FOR DATA COLLECTION

To evaluate the feasibility of using HSI models in inventorying and monitoring biotic resources, we searched the literature for HSI models for species of birds and mammals that occur in the Southern Appalachians. The habitat variables, those variables that are used as input to the HSI models, were recorded and classified into four categories:

1. Standard inventory—variables collected by CIC as part of their standard timber inventory, or that can be derived from data collected as part of the standard timber inventory.

2. Enhanced inventory—variables collected as part of the enhanced timber inventory, or that can be derived from data collected as part of the enhanced timber inventory.

3. Other sources—variables from maps or from a geographic information system that have not been collected specifically as part of the enhanced inventory.

4. Not collected—variables that are not in one of the previous three categories and that must be collected in the field.

RESULTS

Forty HSI models for 34 species of birds and mammals that occur in the Southern Appalachians were evaluated. Table 1 presents the variables and their availability for six HSI models as examples. A table with all of the HSI models is presented in Rennie *et al.* (1997). Examination of these HSI models shows that variables for three species [gray squirrel (*Sciurus carolinensis* Gmelin), hairy woodpecker (*Dendrocopos villosus* (Linnaeus)), and wood thrush (*Hylocichla mustelina* (Gmelin))] were collected, or can be calculated from the standard CIC inventory. Models for six additional species [Acadian flycatcher (*Empidonax virescens* (Vieillot)), black bear (*Ursus americanus* Pallas) (two models), black-throated blue warbler (*Dendroica caerulescens* (Gmelin)), Canada warbler (*Wilsonia canadensis* (Linnaeus)), chestnut-sided warbler (*Dendroica citrina*), and worm-eating warbler (*Helmitheros vermivorus* (Gmelin))] can be used with data that are available from other sources along with the data collected on the standard inventory. Models for two species [downy woodpecker (*Picoides pubescens*) (two models), and hooded warbler (*Hylocichla mustelina*)] can be used with data from the enhanced inventory; one model [eastern wood pewee (*Contopus virens* (Linnaeus))] can be used with data from the enhanced inventory and from other sources. The remaining 26 models require additional data that must be collected in the field as input variables.

DISCUSSION AND RECOMMENDATIONS

Conducting an inventory and subsequently monitoring biotic resources is an essential part of ecosystem management and sustainable forestry. These inventories, like traditional timber inventories, must be conducted at a reasonable cost whether the land is privately or publicly owned.

Use of HSI models driven by variables collected in timber inventories or enhanced timber inventories appears to be a feasible approach. However, each of the models evaluated was developed separately and contains variables specifically related to the critical needs of the individual species being addressed. When only a few species are of concern, as in a featured species approach to wildlife management, the number of variables needed for the HSI models may be manageable. However, when many species are of concern as with ecosystem management, the number of variables needed to evaluate the models becomes exceedingly large. Also, some of the variables required for HSI models are not derived from plot-based data, or from information available from maps, aerial photographs, or

Table 1.—*Types of input variables and their availability for six habitat suitability index models*

Common name Genus and species Citation	Variables in HSI models	Source of variable
Black bear	Overstory vegetation type	Standard inventory[1]
Ursus americanus	Overstory vegetation diversity	Standard inventory
Van Manen and	Elevation	Other sources[2]
Pelton 1993	Proximity to streams	Other sources
	Proximity to human activity	Other sources
	Proximity to roads	Other sources
	Proximity to trails	Other sources
	History of vegetation disturbance	Other sources
	Slope	Other sources
	Aspect	Other sources
	Fire history	Other sources
Black-throated blue	Stand size	Standard inventory
warbler	Oak hickory forest type	Standard inventory
Dendroica	Cove hardwood forest type	Standard inventory
caerulescens	Northern hardwood forest type	Standard inventory
Bartlett 1995	Elevation	Other sources
Downy woodpecker	Number of saplings	Standard inventory
Picoides pubescens	Branch biomass of average tree 1.2-8.4 cm dbh	Standard inventory
Anderson and	Bole biomass of average tree 1.2-8.4 cm dbh	Standard inventory
Shugart 1974	Foliage biomass of average tree 1.2-8.4 cm dbh	Standard inventory
	Stump biomass of average tree 1.2-8.4 cm dbh	Enhanced inventory[3]
Hooded warbler	Cove hardwood forest type	Standard inventory
Hylocichla mustelina	Number of trees in the 53-68 cm dbh size class	Standard inventory
Bartlett 1995	Canopy height	Enhanced inventory
Field sparrow	Percent of total shrubs less than 1.5 m	Enhanced inventory
Spizella pusilla	Average height of herbaceous canopy	Not collected[4]
Sousa 1983	Percent canopy cover of grasses	Enhanced inventory
	Percent shrub crown cover	Enhanced inventory
Ruffed grouse	Forest age class	Standard inventory
Bonasa umbellus	Forest group	Standard inventory
Doan *et al.* 1997	Habitat diversity within home range size	Other sources
	Proximity to daylighted roads	Not collected
	Proximity to evergreen shrub thickets	Not collected

[1] Variable collected as part of standard inventory or derived from data collected in standard inventory.
[2] Data not collected, but available from other sources.
[3] Variable collected as part of enhanced inventory or derived from data collected in enhanced inventory.
[4] Data not in one of the previous categories; must be collected in the field.

other spatial sources addressable with geographic information systems; they would require a separate inventory to acquire. Two examples are proximity to daylighted roads and proximity to evergreen shrub thickets in the HSI model for ruffed grouse (table 1).

Based on these observations, we conclude that a HSI-based approach coupled with the enhanced CIC inventory is not a cost-effective means of measuring biodiversity. Habitat suitability indices could be calculated for only three species with the standard inventory; indices could be calculated with the enhanced database for only three additional models. Another eight models could be added with additional existing data, but the type of data needed and their sources are so varied that, in practice, model calculations would be time consuming and costly. Furthermore, although all the species associated with the 40 models we examined occur in the Southern Appalachian region, many of these models were developed elsewhere in North America and may not be directly applicable to other geographic regions.

An alternate approach is a land- and habitat-based system. This is in contrast to the animal-based approach of HSI models. Developers of these systems have used different names, but one more commonly used is landscape ecosystem classification. These systems use soils, landform, and vegetation to identify homogeneous site units. Once successional and mature vegetation has been described for each site unit, the importance of each vegetational stage is documented on each site unit for a variety of resources including wildlife. This then serves as the basis for management of the forest resources. One area for which a landscape ecosystem classification has been developed with extensive supporting documentation for various forest and wildlife resources is northwestern Ontario. Classification systems have been developed for the Cumberland Plateau and Highland Rim by Smalley (1986) and are being developed by the USDA Forest Service, Southern Research Station (W.H. McNab, personal communication) for the Blue Ridge Province of the Southern Appalachians. However, these systems do not yet have extensive supporting documentation for forest resources other than timber.

Development of a landscape ecosystem classification system is divided into four phases. In phase 1, a model is developed to predict site units from soil and site factors. Site units are mature forest types within the geographic area under study and are identified through analysis of vegetation, soils, and landform data collected in stands with little indication of disturbance. Phase 2 involves describing the various successional stages that develop in each of the site units. In phase 3, specialists in the resources of concern (e.g., timber, wildlife, recreation) evaluate each of the successional and mature vegetation types from their discipline; for example, a wildlife biologist would rate each vegetation type for the various biological needs of each wildlife species in the area. This results in a matrix of vegetation types by uses with cells indicating the evaluations. Phase 4 involves applying the model to predict the presence of site units on the land area under management and to evaluate the impact of management practices through the matrix developed in phase 3. This step depends heavily on geographic information systems, digital elevation models, and other computer intensive techniques. Finally, model verification and refinement is critical. This should be based on both new research and input from users of the model.

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